Space Technology Research Grants

Reducing Risk and Increasing Exploration Payoff with Symbiotic Rover Pairs

Completed Technology Project (2015 - 2017)

Project Introduction

Planetary explorations missions avoid the destinations that offer the greatest scientific payout because these destinations come with a risk too great for a primary rover. The many caves, canyons, and pits that cover the surface of Mars and the Moon have immense scientific value, yet the rugged terrain and precipitous slopes of these features are too dangerous to risk the primary mission asset. The solution to this risk problem is a symbiotic architecture consisting of a primary rover and one or more secondary companion rovers. These secondary rovers would be less expensive, potentially expendable, and capable of exploring hazardous terrain and features without risking the mission if lost. The benefits of a symbiotic architecture extend far beyond simple risk mitigation - the secondary rovers could explore more area efficiently, provide operators with additional viewpoints of objects of interest, and assist operators in debugging problems with the primary rover by providing views that would be otherwise impossible to take. Though symbiotic multi-robot systems have been developed, few have been in the context of hazardous planetary exploration. Those that have, focus primarily on the mechanical challenges of such a system. There are multiple algorithmic challenges relating to coordination between the rovers that are barriers to a symbiotic rover architecture being realized. The proposed research will allow symbiotic rover teams to better navigate and explore hazardous terrain by developing and applying innovative methods in combined path planning, task allocation, and localization. The algorithms developed by this research will enable symbiotic rovers to boldly explore scientific frontiers currently considered beyond-limits by NASA. The proposed research will improve current distance and time constrained multi-robot path planning algorithms by shifting the constraints from the time domain to resource cost domain. This will allow the secondary rover with more limited resources (energy, sample storage, etc.) to rendezvous with the primary rover before the resource is expended. Initial experimentation of the algorithm will be done in simulation by automatically generating the hazard maps and verifying the optimality of the generated paths. If they are consistently successful, the methods and algorithms will be tested in the field with mobile robots. Improved task allocation methods are necessary if the primary and secondary rovers are to best assign waypoints according to their capabilities and constraints. By modeling the challenge of waypoint allocation as one of distributed constraint optimization (DCOP) and combining it with the resource-based path planning discussed above, better allocation of waypoints will be achieved. As the task allocation algorithm is tightly coupled with the path planner, it will be developed and tested in conjunction with it by verifying whether or not the waypoints the rovers choose to travel are optimal given the rovers capabilities. The secondary rover's smaller size and lower processing power may preclude methods of localization currently used by most rovers. This research will investigate methods of localizing the secondary rover absolutely by determining an accurate relative localization to the primary rover, which does not have the same constraints. Initial testing of the algorithm will use sensors

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Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

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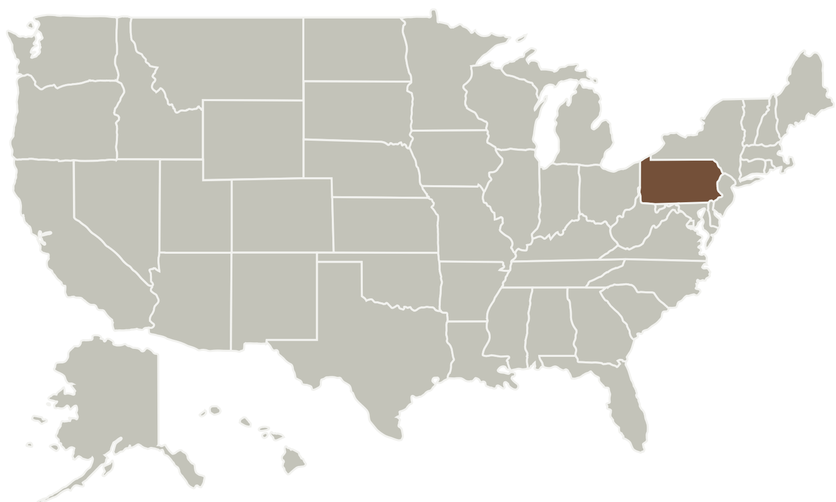
analogous to those the secondary rover would have available. A radio time-distance-of-arrival sensor will be used to determine the distance between the primary rover and secondary rover and a sun sensor will be used to determine absolute orientation. By taking successive readings of these sensors and comparing them to the known location of the primary rover, an accurate absolute localization of the secondary rover can be achieved.

Anticipated Benefits

The proposed research will allow symbiotic rover teams to better navigate and explore hazardous terrain by developing and applying innovative methods in combined path planning, task allocation, and localization. The algorithms developed by this research will enable symbiotic rovers to boldly explore scientific frontiers currently considered beyond-limits by NASA.

Primary U.S. Work Locations and Key Partners



Primary U.S. Work Locations
Pennsylvania

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

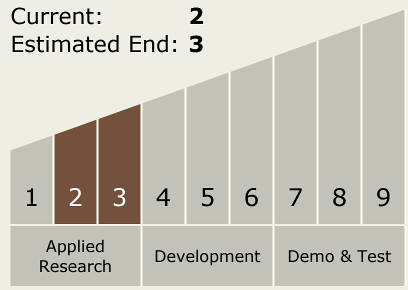
William Whittaker

Co-Investigator:

Joseph L Amato

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX04 Robotic Systems
  └ TX04.2 Mobility
    └ TX04.2.6 Collaborative Mobility